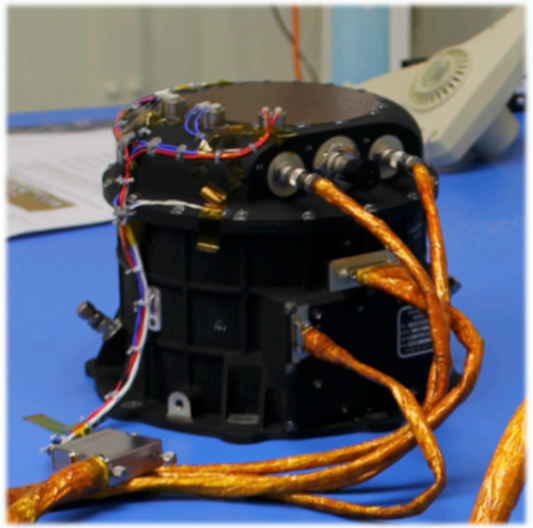
# Using Measurements from the Disturbance Monitoring Package in SAGE III/ISS Data Processing



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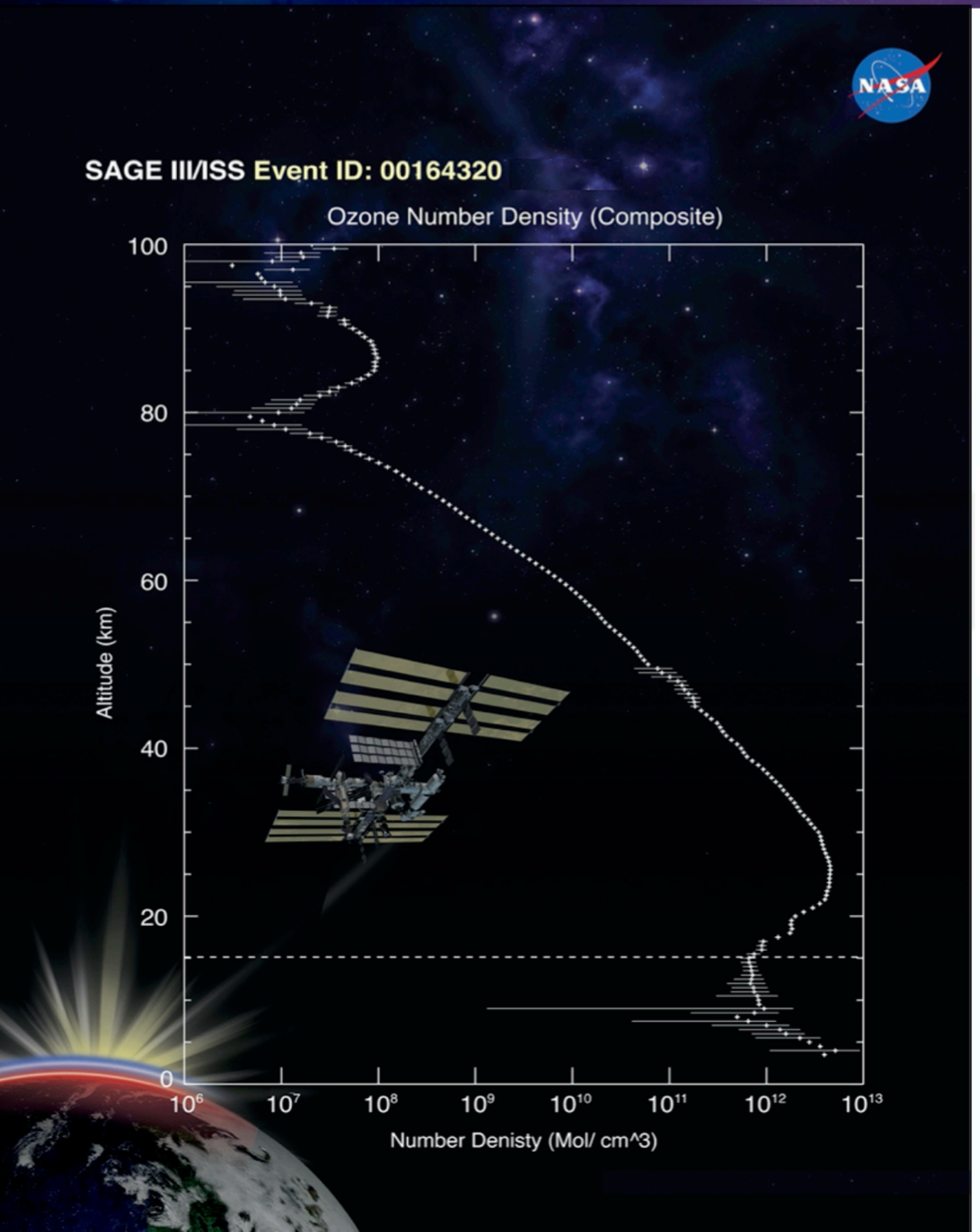
# SAGE III/ISS – Latest in the SAGE Series of Occultation Instruments




## SAGE III/ISS Retrieves Profiles of :

- $O_3$, $NO_2$, Aerosols, $H_20$ Vapor
- Other trace gases

## Occultation Measurement Technique is performed by:

- Scanning Radiant Target (Sun/Moon) through the atmosphere
- Transmission is then converted to vertical profiles
- Requires precise pointing knowledge of the target
- Prior Missions operated in benign Mechanical Vibrational Environment

## Tracking & Scanning Radiant Target accomplished by:

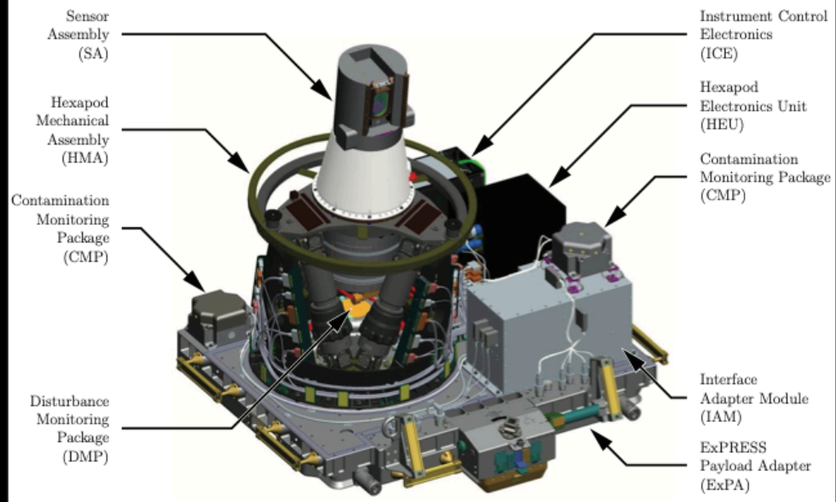
- Azimuth rotor assembly
- Elevation Scan Mirror
- [ISS] Disturbance Monitoring Package

## [ISS] International Space Station experiences attitude fluctuations caused by:

- Maintaining TEA (torque equilibrium attitude)
- Reboosts, Dockings, Maneuvers
- Pointing precision requirement < 30 arcsec
- 10% Events Impacted by disturbances

# SAGE III/ISS – Sage III Payload & Disturbance Monitoring Package

## SAGE III Payload




## Disturbance Monitoring Package

## SAGE III Payload is comprised of 5 subsystems:

- Sensor Assembly [SA]
- Hexapod Mechanical Assembly [HMA]
- 2 Contamination Monitoring Packages [CMP]
- Disturbance Monitoring Package [DMP]
- Interface Adapter Module [IAM]

## Attitude Fluctuations are measured by a Disturbance Monitoring Package [DMP]:

- Miniature Inertial Measurement Unit [MIMU]
- 3 Ring Laser Gyroscopes
  Sensitive to rotations as small as
  1 $\mu$ radian @ 200 Hz [ .001 arcsec / sec ]
- 1 $\mu$ radian in elevation → 0.7m – 2.5 m in tangent height registration from a 400km orbital altitude
- Significant as only 30m of the 100m altitude error budget are allotted to spacecraft attitude

# SAGE III/ISS – Transformation of DMP Measurements into Instrument Boresight

## Coordinate Systems

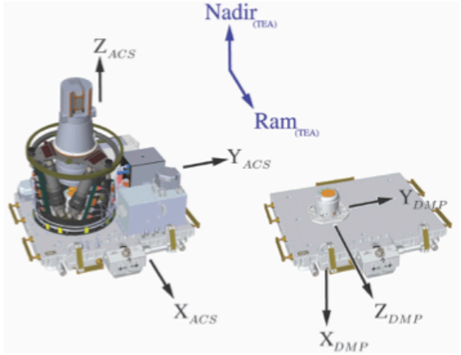



Figure 3

## Instrument Boresight


Figure 4

## DMP Elevation Correction

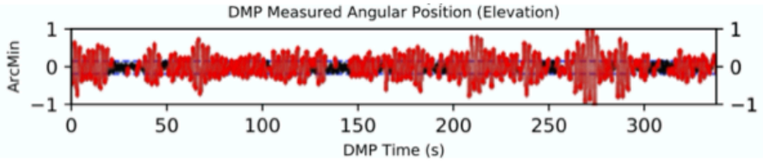



Figure 5

## ACS and DMP Coordinate Systems:

- [ACS] Analysis Coordinate System fixed to ISS
  - ACS Z-axis → Nadir [normal TEA attitudes]
  - ACS X-axis → RAM [normal TEA attitudes]
- DMP is oriented to ACS such that axes form [normal TEA attitudes]:
  ~90 rotation about the $Y_{ACS}$,$Y_{DMP}$ shared axis
  Other ACS orientations are possible but less common

## Transform DMP Measurements → [Elevation, Azimuth Roll]:

- Remove Orbital Motion
- Filter Dither using Butterworth Filter
- Convert Gyro Positions to Rates
- Rotate through Quaternions:
  -Hexapod [HMA]
  -Static [alignment error due to
  -Wedge
  -DMP → SA Coordinate Transformation

## DMP Elevation Correction [DMP Offset]:

- Map into Boresight Frame using Azimuth, Elevation Angles
- Mark Exceedances
- Down Sample to 64 Hz

# SAGE III/ISS – Pointing Registration & Lower Atmospheric Corrections

## Pointing Registration Correction

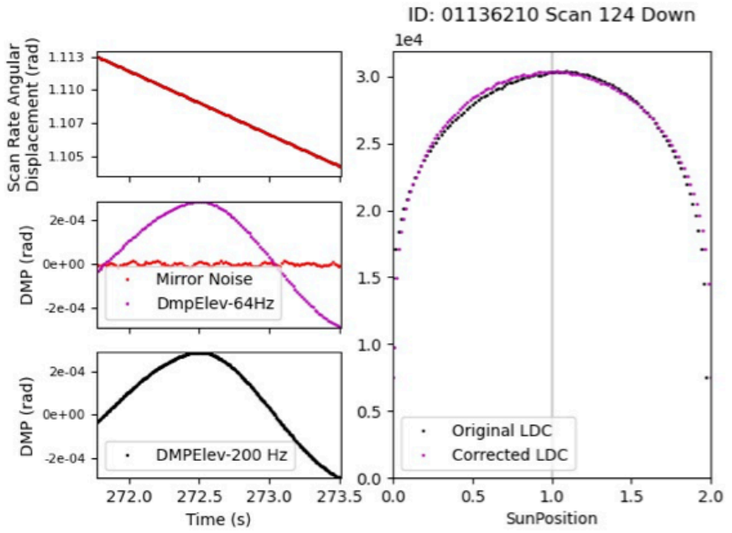



**Figure 6**

[Without DMP Correction (Black) and With DMP Correction (Magenta)]

## Lower Atmospheric Correction

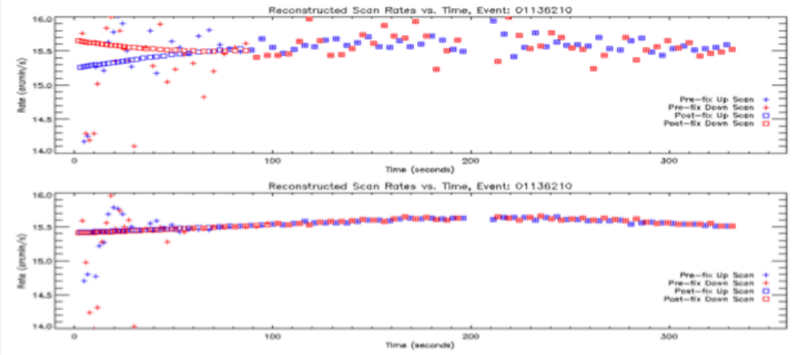



**Figure 7**

## Pointing Registration Correction:

- Assigns solar positions by scaling angular displacements from Nadir using a calculated Scan Rate as,

  [Scan Rate = top edge-bottom edge/time difference]

- DMP correction for the same interpolated time is added

***Fig 6 Left: Time series for Scan Rate Displacement, & DMP Offset***

***Fig 6 Right: Limb Darkening Curves***

## Lower Atmospheric Scan Rate Correction:

- Sun becomes occluded requiring Exo-Atmospheric scan rate extrapolation
  ***Fig 7 Top: diverging red & blue boxes***

- DMP Offset added to Exo-Atmospheric , corrected scans then result in an improved lower atmosphere extrapolation
  ***Fig 7 Bottom: aligned red & blue boxes***

# SAGE III/ISS – Pointing Registration Animation 1

## Pointing Registration Correction

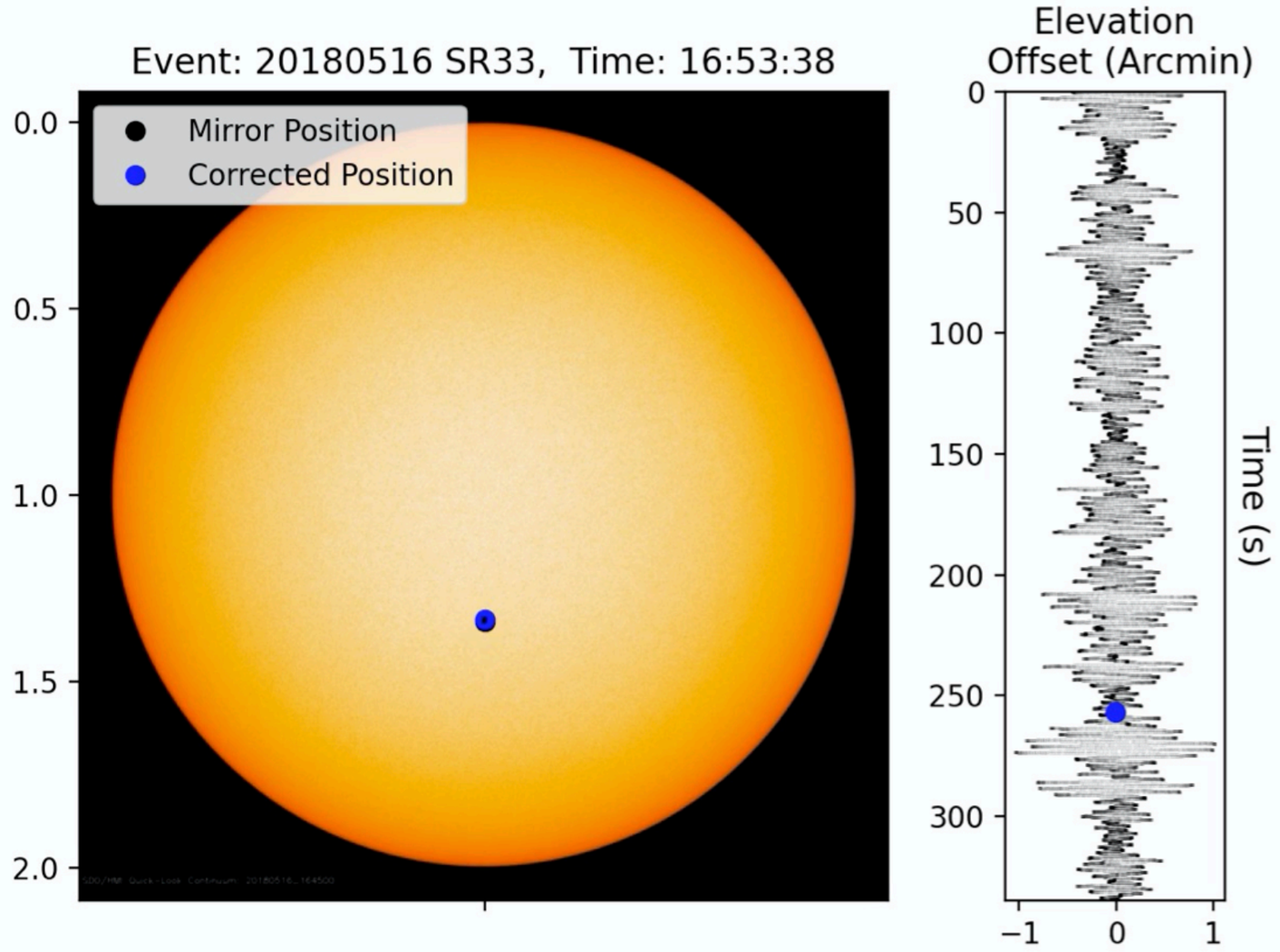
- Assigns solar positions by scaling angular displacements from Nadir using a calculated Scan Rate
- DMP correction for the same interpolated time is added

## Animations

- Left Plot:
  SDO HMIIC image
  OverPlotted w angular positions
  w & wout DMP correction
- Right Plot:
  Elevation Offset added
  to angular displacement

*Note* Depending on Disturbance angular rate and direction compared to those of the Mirror, the DMP Corrected Solar Position will lead or lag the Mirror Position*

Without DMP Correction (Black)
With DMP Correction (Blue)



# SAGE III/ISS – Pointing Registration Animation 2 – *Wavelength 601 nm*

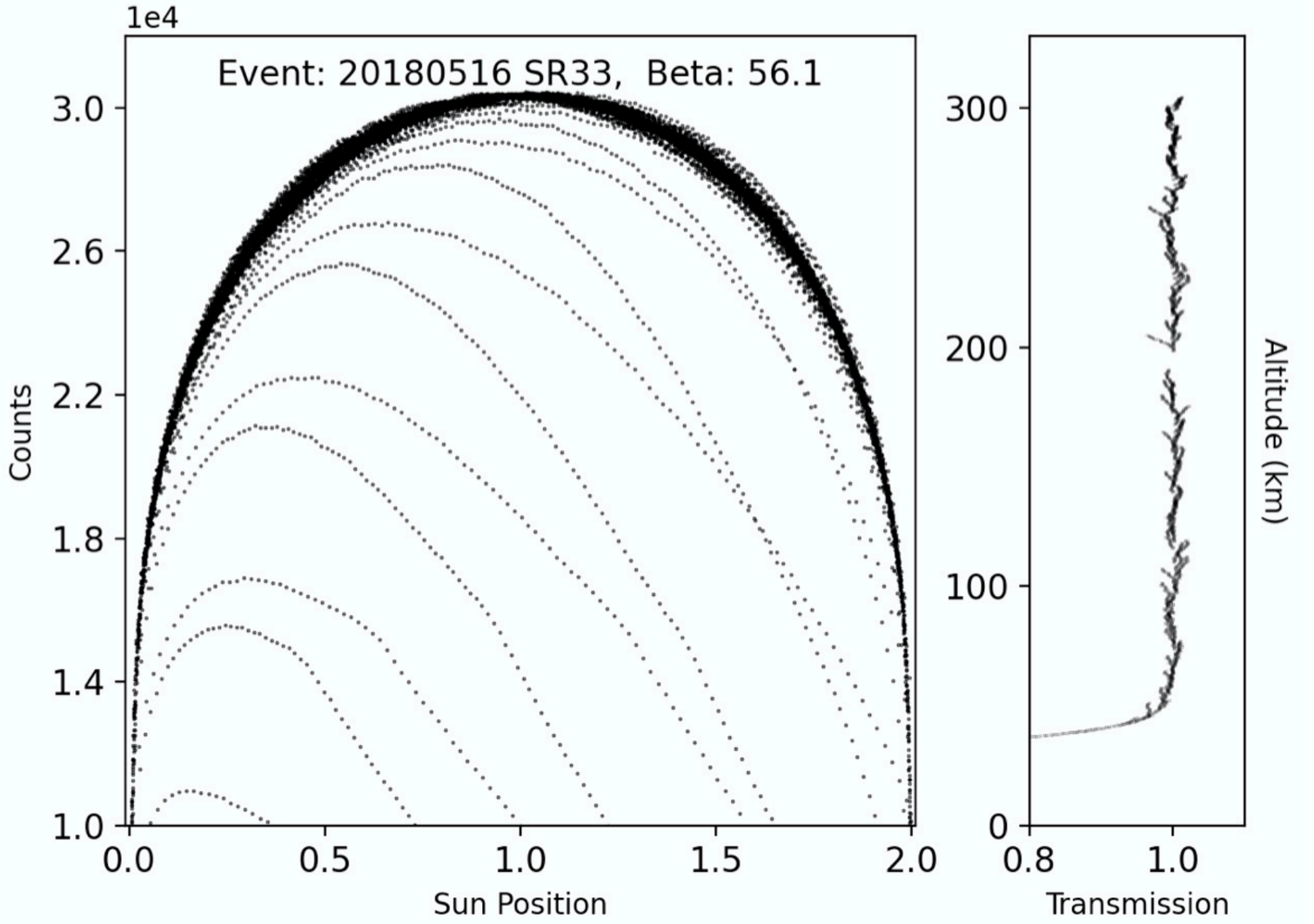
## Pointing Registration Correction

To Illustrate effect of the DMP Correction, an animation iterates through events showing Level 1 Intensity and Transmission Data

- 50 Events: Largest # Disturbances
- BEFORE –and- AFTER Correction
- Left Plot:
  Solar Intensity vs Sun Position
- Right Plot:
  Transmission vs Altitude

Without DMP Correction (Black)
With DMP Correction (Blue)

*Note* Events w Sunspots*



# SAGE III/ISS – Level 1 / Level 2 Data Product Improvements

## Level 1 Transmission

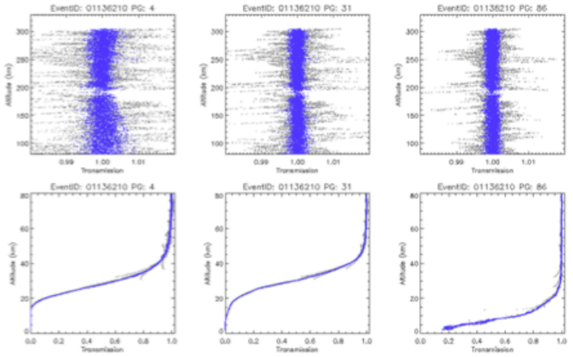


Figure 8

## Level 2 Data Products

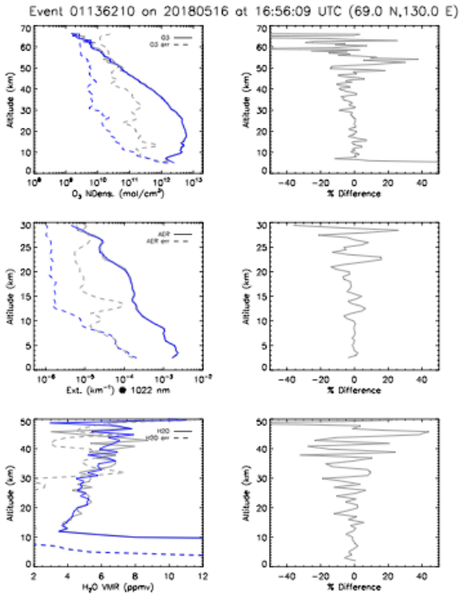



Figure 9

[Gray without DMP Correction, Blue with DMP Correction]

## Level 1 Transmission Improvements:

Fig 8 Unbinned Transmission for wavelengths (385, 601, & 1020 nm)

- [Top Row] Exo Atmospheric DMP corrects disturbances reliably
  - Order of Magnitude Decrease in noise
  - Similar Results observed for Entire Exo-Atmospheric Dataset
- [Bottom Row] Lower Atmosphere Disturbance present, smaller for this event, correction still performs reliably
  - Changes in overall pointing registration where large transmission gradients exist

## Level 2 Retrieval Improvements:

Fig 9 [Left] Retrievals & Uncertainties for O3, 1 $\mu$ Aerosol, & H2O Vapor
Fig 9 [Right] Percent Differences for each Retrieval

- Reduction in Retrieval Uncertainties
- Reduction in Retrieval Noise itself
  - Note H20 Vapor reduction which is specifically sensitive to Transmission noise
- Beginning to Investigate the effects of the DMP Correction on the SAGE III/ISS Dataset as a whole

# SAGE III/ISS – Summary

## To Summarize:

- Sage operates on the ISS
- ISS experiences Attitude Fluctuations
- DMP Corrects for Pointing Mis-Registrations in 10% Events
- Level 1 & 2 Data Products result in lower uncertainties

## Future Work:

- Analyzing Entire Dataset using DMP Correction
- Investigate Other Potential Improvements
  - Fine tune Filter Cutoff Frequency
  - Incorporate Azimuth & Roll Offsets
  - Incorporate DMP Flag for high level disturbances
  - Improve Understanding of:
    -Coordinate Transformation
    ACS → DMP → SA
    -Mechanical Transfer Function

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and Space Administration
*Langley Research Center*